

Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.



A



B



C

D

D. G. Passmore

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 108.

B. T. GALLOWAY, *Chief of Bureau.*

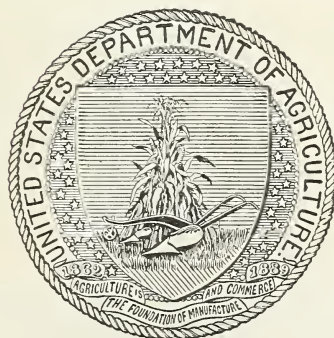
THE COLD STORAGE OF SMALL FRUITS.

BY

S. H. FULTON,

FORMERLY ASSISTANT POMOLOGIST, FIELD
INVESTIGATIONS IN POMOLOGY.

ISSUED SEPTEMBER 9, 1907.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1907.

BUREAU OF PLANT INDUSTRY.

Pathologist and Physiologist, and Chief of Bureau, Beverly T. Galloway.
Pathologist and Physiologist, and Assistant Chief of Bureau, Albert F. Woods.
Laboratory of Plant Pathology, Erwin F. Smith, Pathologist in Charge.
Investigations of Diseases of Fruits, Merton B. Waite, Pathologist in Charge.
Plant Life History Investigations, Walter T. Swingle, Physiologist in Charge.
Cotton and Tobacco Breeding Investigations, Archibald D. Shamel, Physiologist in Charge.
Corn Investigations, Charles P. Hartley, Physiologist in Charge.
Alkali and Drought Resistant Plant Breeding Investigations, Thomas H. Kearney, Physiologist in Charge.
Soil Bacteriology and Water Purification Investigations, Karl F. Kellerman, Physiologist in Charge.
Bionomic Investigations of Tropical and Subtropical Plants, Orator F. Cook, Bionomist in Charge.
Drug and Poisonous Plant Investigations and Tea Culture Investigations, Rodney H. True, Physiologist in Charge.
Physical Laboratory, Lyman J. Briggs, Physicist in Charge.
Crop Technology Investigations, Nathan A. Cobb, Expert in Charge.
Taxonomic Investigations, Frederick V. Coville, Botanist in Charge.
Farm Management Investigations, William J. Spillman, Agriculturist in Charge.
Grain Investigations, Mark A. Carleton, Cerealist in Charge.
Arlington Experimental Farm, Lee C. Corbett, Horticulturist in Charge.
Sugar-Beet Investigations, Charles O. Townsend, Pathologist in Charge.
Western Agricultural Extension Investigations, Carl S. Scofield, Agriculturist in Charge.
Dry Land Agriculture Investigations, E. Channing Chilcott, Agriculturist in Charge.
Pomological Collections, Gustavus B. Brackett, Pomologist in Charge.
Field Investigations in Pomology, William A. Taylor and G. Harold Powell, Pomologists in Charge.
Experimental Gardens and Grounds, Edward M. Byrnes, Superintendent.
Vegetable Testing Gardens, William W. Tracy, sr., Superintendent.
Seed and Plant Introduction, David Fairchild, Agricultural Explorer in Charge.
Forage Crop Investigations, Charles V. Piper, Agrostologist in Charge.
Seed Laboratory, Edgar Brown, Botanist in Charge.
Grain Standardization, John D. Shanahan, Expert in Charge.
Subtropical Laboratory and Garden, Miami, Fla., Ernst A. Bessey, Pathologist in Charge.
Plant Introduction Garden, Chico, Cal., August Mayer, Expert in Charge.
South Texas Garden, Brownsville, Tex., Edward C. Green, Pomologist in Charge.
Cotton Culture Farms, Seaman A. Knapp, Lake Charles, La., Special Agent in Charge.

Editor, J. E. Rockwell.

Chief Clerk, James E. Jones.

FIELD INVESTIGATIONS IN POMOLOGY.

SCIENTIFIC STAFF.

William A. Taylor, Pomologist in Charge of Fruit Marketing Investigations.
G. Harold Powell, Pomologist in Charge of Fruit Transportation and Storage Investigations.
George C. Husmann, Pomologist in Charge of Viticultural Investigations.
A. V. Stubenrauch, Expert in Fruit Transportation.
H. P. Gould, Pomologist in Charge of Fruit District Investigations.
L. S. Tenny, Pomologist in Fruit Marketing, Transportation, and Storage.
S. H. Fulton,^a Assistant Pomologist in Fruit Marketing and Storage Investigations.
S. J. Dennis, Expert in Refrigeration.
H. J. Eustace, Expert in Fruit Storage.
George W. Hosford, Assistant Pomologist in Fruit Marketing, Transportation, and Storage.
Alfred Tournier, Special Agent in Viticultural Investigations.
W. F. Fletcher, Scientific Assistant in Fruit District Investigations.
H. M. White, Scientific Assistant in Fruit Marketing, Transportation, and Storage.
E. F. Cole, Scientific Assistant in Viticultural Investigations.

^a Resigned in April, 1906.

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., April 12, 1907.

SIR: I have the honor to transmit herewith a manuscript entitled "The Cold Storage of Small Fruits" and to recommend that it be published as Bulletin No. 108 of the series of this Bureau. This bulletin was prepared by Mr. S. H. Fulton, formerly Assistant Pomologist in Field Investigations in Pomology, and has been submitted by Messrs. William A. Taylor and G. Harold Powell, Pomologists in Charge of Field Investigations in Pomology, with a view to publication.

The subject is an important one to small fruit growers in many portions of the country, and it is believed that the results of the investigations set forth will be found useful by suggesting ways of prolonging the marketing season and thus conducing to a better distribution of the product, as well as by indicating some of the risks that are involved in attempts to hold such products longer than their inherent physical characteristics permit. The fundamental importance of careful attention to the details of harvesting, packing, and handling is emphasized by the results of this work, as well as the necessity of proper ventilation of rooms and isolation of products in storage houses to preserve the normal color, texture, and flavor of these delicate fruits.

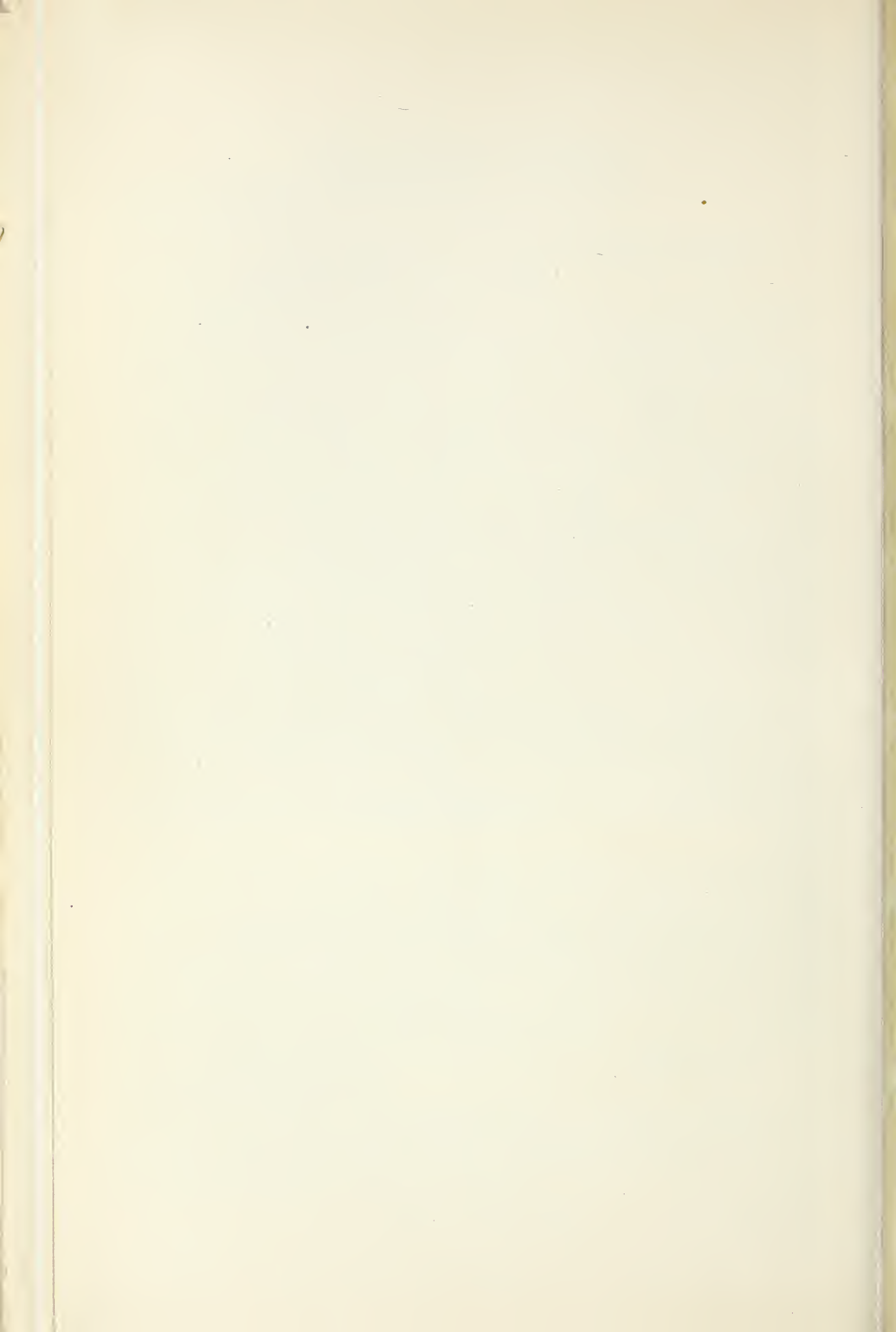
The work covered by this report has been done by Mr. Fulton, while the investigations of the gases that accumulate in packages of stored fruit and of the effect of oxygen gas upon stored fruit have been made by Mr. H. C. Gore, of the Bureau of Chemistry, in cooperation with this Bureau.

The accompanying illustrations are necessary to a full understanding of the text.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.



CONTENTS.

	Page.
Introduction	7
Outline of experiments in small-fruit storage	10
The influence of soil and climatic conditions on the keeping quality of small fruits	11
The influence of the time of picking on the keeping quality of small fruits...	12
Storage house temperatures for small fruits.....	12
The freezing of small fruits in cold storage	13
The influence of the type of package on the keeping quality of small fruits ...	14
Composition of the air in different types of packages.....	15
The influence of the wrapper on the keeping quality of small fruits	17
The influence of oxygen gas on the keeping quality of small fruits.....	18
The influence on the keeping quality of careful handling and of storing small fruits soon after picking	19
The length of time small fruits keep in cold storage	20
The behavior of small fruits when withdrawn from cold storage	21
Summary	21
Description of plates.....	26
Index	27

ILLUSTRATIONS.

PLATES.

	Page.
PLATE I. Gandy strawberries. <i>A</i> , after twenty-one days in cold storage at a temperature of 32° F. <i>B</i> , after seven months in a frozen condition in storage at a temperature of 12° F. <i>C</i> , showing discoloration of the fruit from bruising. <i>D</i> , showing mold forming on a bruised spot.....	Frontispiece.
II. Packages and wrappers used on berries in cold storage. Fig. 1.—Cartons in which fruit was frozen. Fig. 2.—A box of strawberries wrapped with japanin paper and one unwrapped. Fig. 3.—Black raspberries wrapped with japanin paper and unwrapped, packed in a Hallock crate.....	26
III. Black mold on strawberries and black raspberries in cold storage. Figs. 1 and 2.—Black mold on black raspberries. Figs. 3 and 4.—Black mold on strawberries.....	26

THE COLD STORAGE OF SMALL FRUITS.

INTRODUCTION.

The beneficial influence of cold storage on fruit growing in America has not been shared equally by all branches of the industry. Some kinds of fruit are better adapted to storing in cold temperatures than others, and are in active demand through a longer season. Winter apples and pears can be kept in good condition for long periods in cold storage, and a large part of the late apple and pear crops of the United States is now held in cold storage annually to insure a supply of these fruits in good condition throughout the winter and spring months. Upon the other hand, berries and other small fruits are not stored to nearly so great an extent on account of their highly perishable nature.

The storage of small fruits is a problem somewhat different from the storage of the more durable fruits. Winter apples and pears are usually too hard and immature when stored to be fit for immediate consumption. Cold storage insures the safe keeping of these fruits for long periods, and under proper management brings out their finest flavor and quality. The fruits ripen slowly in the low temperature of the storage house, the acids diminish, the starch changes to sugar if the transformation is not already completed when the fruit is stored, and the fine flavor and aroma of the fruit are developed.

In the storage of small fruits the conditions and purposes are different. The strawberry, for example, is usually developed to the highest state of perfection when picked; the quality is not improved by further ripening, and the fruit needs to be consumed quickly. All that can be hoped for from cold storage is to preserve for a short period the attractive appearance and fine flavor of the fruit.

In commercial practice, small fruits are sometimes stored for speculative purposes. The fruit is bought when the market is low; it is stored until prices advance, and it is then sold at a profit. Owing to the extremely perishable nature of most of the small fruits, however, this must be regarded as a hazardous practice. The great bulk of small fruits held in cold storage is placed there to protect the fruits temporarily from decay until they can be placed in the hands of the consumer. Shipments of small fruits are frequently delayed in transit

and reach their destination too late for the early morning market. There is often little opportunity of disposing of them until the following morning, or in case the late arrival occurs on Saturday the fruit can not be sold until the following Monday morning. Without artificial refrigeration, the fruit would deteriorate rapidly, and in many instances would become worthless before it could be sold. Under these conditions it may be saved by placing it temporarily in cold storage. An overstocked market sometimes results in the cold storing of considerable quantities of small fruits when there is a reasonable prospect for a stronger demand and better prices within two or three days.

Cold storage is now used for small fruits by many canning establishments. At the height of the season, the fruit is often received faster than it can be cared for. The surplus is then placed in cold storage to be held until it can be packed in the cans. Some of the best equipped canneries in this country are now supplied with their own cold-storage facilities.

In some sections, particularly in the Hudson River Valley of New York, small-fruit growers have built farm storage houses, cooled by ice or by a mixture of ice and salt, with a view to handling their crops to better advantage. The berries are placed in these houses as fast as picked, and held until the output of the day is ready for shipment. The fruit may be held from one day to the next before shipping, or even for a longer period if desired in the case of firm-fleshed varieties, and still reach the market in good condition. It has been found that berries cooled down before shipping will carry in better condition than they do when shipped in a warm condition.

Another phase of cold storage of small fruits that is assuming considerable importance is the freezing of the fruit for use by confectioners, bakers, and restaurateurs, the fruit being held in a frozen condition for use in ice cream, pastries, etc.

In view of the difficulties involved in storing and the long season during which fresh-picked supplies can be obtained from various sections of the country, the use of cold storage for small fruits will continue to be restricted mainly to the preservation of the fruit for a brief period when otherwise it would be lost. But in this field alone cold storage serves a very important mission, for in many of the large cities of the country great quantities of berries are annually stored for brief periods for one or more of the reasons already stated. In New York, for example, thousands of crates of berries are sometimes stored in a single day in the cold-storage houses within or near the produce district.

There is very little information published relative to the cold storage of small fruits, and such as is available is based primarily upon obser-

vation of the conditions surrounding the fruit in the cold-storage house. Little consideration appears to have been given the conditions surrounding the growing and handling of the fruit, though these conditions very largely determine the behavior of all kinds of fruits in cold storage. The only record of a systematic test of the keeping of small fruits in cold storage which has come under our observation is a report of a series of experiments performed in England in 1898. The results of this test are given in the *Journal of the Board of Agriculture of Great Britain* for June, 1899 (p. 85), under the title "Cold Storage of Fruit." Extracts from this article are here given:

The board of agriculture have received from the Kent County council a report by Mr. W. P. Wright, F. R. H. S., superintendent of horticulture under the technical education committee, upon the results of experiments on the cold storage of fruit. Three cold chambers were used, each fitted with two brine walls or flat tanks placed in close proximity to the insulated sides of the chamber; through these tanks brine cooled by a carbonic anhydride refrigerating machine was circulated at any desired temperature. Each chamber was fitted with tiers of galvanized wire shelves around the sides, and the fruit was placed on these under three different conditions: (1) Exposed on the shelves, (2) enveloped in grease-proof paper, (3) surrounded or covered by cotton-wool. It was found that strawberries could be kept for at least three weeks in a temperature of 30°, but it was necessary to surround the fruit with cotton-wool, or, in the case of fruit in sieves, to place a pad of that material over the top. When this precaution was not taken, the fruit, though sound, became dull and lost the fresh, inviting appearance which is so important when it is offered for sale. Black currants kept well for ten days, after which they began to shrivel, but plumped and freshened on exposure to the air so as to be marketable. This was especially the case with black currants that had been stored in market sieves covered with a wad of cotton-wool. After a fortnight's storage, the temperature was raised from 30° to 32° F., and this seemed to give the best results. The experiments with red currants were an unqualified success, the fruit remaining perfectly sound for six weeks, and maintaining its freshness when exposed to a normal temperature for sixteen hours. Cherries covered with wool kept for a month at a temperature of 30°, and at 36° were not only sound, sweet, and juicy, but fresh and clear. After the fourth week the fruit began to wrinkle.

The small fruits above mentioned, and particularly strawberries, must, it appears, be placed in store in advance of dead ripeness; when fully ripe they will keep for some time, but lose surface freshness; the fruit must be sound, and not pecked or injured in any way. * * *

In concluding his report Mr. Wright observes that, in his opinion, people do not quickly weary of high-class fruit, and a longer season than at present exists could be secured for many kinds if the best quality were ensured; but, apart from this, there are periods within the season of several perishable fruits—black currants, for instance—when ability to hold the pickings over, if only for a few days, would mean securing an enhanced price.

The results of this test agree in general with the results obtained through the cold-storage experiments of the United States Department of Agriculture as to length of time small fruits may be kept in cold storage.

OUTLINE OF EXPERIMENTS IN SMALL-FRUIT STORAGE.

Since September, 1901, many problems relating to the cold storage of fruits have received attention in connection with the field investigations in pomology of the Bureau of Plant Industry. For three years of this period the small fruits have been given special attention.

In these experiments the factors affecting the keeping of small fruits in cold storage, such as the influence of soil and climatic conditions, the time of picking, the methods of handling, the types of packages, wrappers, and the temperatures in the storage house have been under investigation. The effect of cold storage on the flavor and aroma of the fruit and the behavior of the fruit when withdrawn from storage have also received consideration.

Subsequent investigations of the Bureau of Plant Industry will bear upon a number of these problems, and while the principles laid down in this publication as a result of the tests are believed to be correct, they may be modified more or less by the additional light afforded by subsequent experiments. This report, therefore, should be regarded as preliminary rather than as conclusive and final.

The principal varieties of small fruits used in the experiments are as follows: Johnson Early, Tennessee, and Gandy strawberries; Early Harvest and Erie blackberries; Miller, Kansas, and Doolittle raspberries; Lucretia dewberries; Howard Bell cranberries; Versailles currants, and Houghton gooseberries. From eight to twenty-four 16-quart crates of each variety were generally used in each season's test. These fruits, with the exception of the cranberries, which were obtained from a New Jersey grower, were furnished by a number of small-fruit growers in Alexandria and Fairfax counties, Virginia. The fruit was brought to Washington by wagon, all of the growers being located within 8 to 10 miles of the storage house, and was stored from four to eight hours after picking in the cold-storage department of the Center Market, at Washington, D. C.

The names of the several small-fruit growers from whom fruit was procured, and the principal varieties furnished by each, are as follows: Brown, J. K., Alexandria, Va., Versailles currants, Houghton gooseberries, and Early Harvest blackberries.

Durell, E. H., Bell Plain, N. J., Howard Bell cranberries.

Leonard, David, Westend, Va., Gandy and Tennessee strawberries, and Kansas raspberries.

Sherwood, D. C., Westend, Va., Tennessee strawberries, Doolittle and Miller raspberries, Lucretia dewberries, and Erie blackberries.

Shreve, R. E. T., Westend, Va., Johnson Early strawberries.

Sprankle, W. T., Falls Church, Va., Early Harvest blackberries.

Most of the fruit used in these experiments, except the cranberries and one series of Gandy strawberries, which were grown upon clay soil, was grown upon reddish, gravelly loam soil with clay subsoil, at an altitude of a little more than 100 feet above sea level.

The fruit, with the exception of the cranberries (which were in barrels and boxes), was packed in the open-slat crates commonly used in the middle and southern berry-growing districts, and also for contrast in the closer, more compact Hallock crate used in the berry sections of Michigan and other western States. For the purpose of testing the effect of a close package, some of the fruit was also packed in paraffined paper cartons wrapped with a calendered paper jacket. Two of these packages are shown in Plate II, figure 1. During the season of 1905 some of these cartons were wrapped in heavy paraffin paper, the whole being then inclosed in the paper jacket. The effect of wrapping was also tested both by wrapping each box or basket separately in thin, impervious japanin paper and by wrapping the entire crate in heavy manila paper.

Upon arrival at the storage house, part of the fruit of a number of the pickings was delayed a few hours in the corridors before it was placed in the storage room, while the remainder was stored at once. The fruit was stored in two temperatures, namely, 36° and 32° F. Samples of each lot were held out of storage to compare with the cold-stored fruit.

THE INFLUENCE OF SOIL AND CLIMATIC CONDITIONS ON THE KEEPING QUALITY OF SMALL FRUITS.

These experiments indicate that the character of the soil may influence the keeping quality of small fruits to some extent, though the data along this line are only suggestive. Berries grown to a large size upon low, moist, clay loam, for example, usually began to break down more quickly than the same variety grown to a somewhat smaller size upon the moderately dry gravelly loam. No comprehensive test of the influence of soil types on the keeping of the fruit has been undertaken.

The keeping quality of small fruits is quickly affected by changes in climatic conditions. Berries ripening during a period when the supply of moisture is favorable for the development of sound, healthy fruit, keep better than the same variety stunted by drought or overgrown by excessive rainfall. Strawberries of the Tennessee variety in 1903 kept poorly when picked during a drought at the opening of the season, but following two days of rainy weather, which supplied a sufficient amount of moisture, the fruit kept well for seven to ten days. After eight days of rainy weather, however, the fruit was overgrown and soft when stored, and after five days in storage was worthless.

Some varieties are much more easily affected by excessive rains than others. The Tennessee strawberry, for example, will be softened and rendered almost unmarketable by a rainfall which would not seriously affect the Gandy variety.

THE INFLUENCE OF THE TIME OF PICKING ON THE KEEPING QUALITY OF SMALL FRUITS.

Small fruits designed for cold storage should be picked when well matured and fully colored, but while still in firm condition. If harvested in an immature condition the flavor is poor and insipid, as immature fruit does not develop properly after picking. This being the case, small fruits for cold storage should be practically as well matured when picked as fruit that goes directly to market for immediate consumption.

In the case of nearly all varieties of berries used in the experiments, three pickings were made for storage, the first early in the season of the variety, the second at the height of the season, and the third as late in the season as a good picking could be secured. No difference in the keeping of the fruit from the several pickings could be detected, providing the weather and other conditions were uniform throughout the season of the variety.

STORAGE HOUSE TEMPERATURES FOR SMALL FRUITS.

In these investigations considerable quantities of small fruits have been stored in duplicate lots in temperatures of both 32° and 36° F. At the lower temperature the fruit has kept in firm condition longer, was somewhat less affected by mold, and held up equally as well or better after withdrawal from the warehouse than that stored in a temperature of 36° F. Unless the fruit was stored for a period of four or five days or longer these differences did not become noticeable.

The impression held by many warehousemen and fruit handlers that low temperatures (32° to 33° F.) are injurious to berries and other quick-ripening fruits has not been borne out by these investigations. Gandy strawberries of the crop of 1903 kept twenty-one days in a temperature of 32° F. and retained their bright, attractive appearance to a remarkable degree. The condition of the fruit after twenty-one days in cold storage is shown in Plate I, A. Other varieties have kept equally well for a somewhat shorter period. No discoloration of the flesh of any of the varieties has occurred as a result of the lower storage temperature.

Small fruits are stored in most warehouses at temperatures ranging from 35° to 40° F. These temperatures give satisfactory results if the fruit is to be stored not longer than two to three days. If, however, the fruit is stored for a longer period of time a temperature of about 32° F. will preserve it in better condition.

THE FREEZING OF SMALL FRUITS IN COLD STORAGE.

In some of the large cities the practice of freezing small fruits for the purpose of holding them indefinitely in a frozen condition to be used in making ice cream and pastries has recently come into use to a limited extent among confectioners, bakers, and restaurateurs. Much of the fruit used for this purpose is bought when the market price is low, such as on Saturday evenings or when the market is glutted. It is hurried into cold storage and is frozen at a temperature ranging from about 5° to 12° F. This fruit is used during the normal small-fruit season, if necessary, or may be held to prolong the season for several weeks, or even months in the case of some of the small fruits. By freezing the fruit a large amount may be kept on hand, thereby avoiding the danger of a temporary shortage in the supply. Some restaurateurs who formerly made a practice of packing berries in dry granulated sugar and of holding them at a temperature of 31° to 32° F. have now given up this practice and have adopted the freezing method.

If the fruit is intended for long preservation it is usually placed in loosely covered tin cans to prevent evaporation, but if it is to be kept a short time it is frequently stored in the ordinary crates in which it is conveyed to market. In the tests of the Bureau of Plant Industry of 1904-5 Gandy strawberries were frozen and held at a temperature of 10° to 14° F. for ten months in the tight paper-wrapped cartons of paraffined cardboard already mentioned, with very little change in color and practically no shrinkage. The condition of berries that had been in storage over seven months in a temperature of 10° F. is shown in Plate I, *B*. Berries frozen in open crates at the same time evaporated and shrunk away fully one-half within a few months.

In June, 1905, strawberries of the Gandy and Tennessee varieties and Miller and Kansas raspberries were frozen and stored in different styles of packages in a temperature of 12° F. in a general freezing room containing meats, poultry, game, etc. The packages used were (1) the paper-wrapped paraffined cardboard carton shown in Plate II, figure 1; (2) the same carton with an additional heavy paraffined paper wrap over the cardboard, which with the outside paper jacket constituted a triple-thick carton; and (3) the common open slat berry crate used in this section. This fruit was still normal in appearance on January 12, 1906, except for a slight fading in the color of the strawberries and a slight shrinkage of both strawberries and raspberries in the open crates. The fruit in the closed packages was plump and attractive in appearance. The flavor of the fruit of both strawberries and raspberries in the open crates was not good. Apparently the fruit had absorbed odors from other articles in the storage room.

The flavor of the fruit in the triple box was a little better, but it had evidently been tainted through the effect of the carbon-dioxid gas exhaled by the fruit before it was solidified in freezing. The flavor of the fruit in the double-wrapped carton, however, which was not so impervious to the air, was not contaminated, and it retained much of the sprightliness and flavor of the fresh fruit. This test seems to indicate that for frozen fruit, as in the case of fruit stored at a temperature above the freezing point, the best results can be obtained by the use of a close package, provided the package is not so tight as to prevent the escape of the gases given off by the fruit after it is packed and before it is frozen.

Frozen strawberries for ice cream have been in use in a limited way by confectioners for some time, while frozen blackcap raspberries, currants, blackberries, huckleberries, and other small fruits are now being used successfully for pies and other pastries by a few restaurateurs and bakers. A large pie bakery in a central western city is successfully using frozen blackcaps, gooseberries, blackberries, currants, and huckleberries in large quantities. When made into pies the flavor of the frozen fruit is said to be practically equal to that of fresh fruit. Considerable quantities of cherries and damson plums are also frozen by this company for use in pies. Usually these latter fruits are put into the pies whole without seeding. Sometimes they are dipped in cold water to take out the frost and then are pitted. Frozen cherries and plums shrivel somewhat in baking, and are therefore not used so successfully as some of the berries. Frozen strawberries have not been used for pies to any extent, as they are likely to soften unduly in baking. Frozen huckleberries and currants can be easily and successfully held for many months. In 1905 the firm referred to above froze 14 carloads of huckleberries, using the fruit in pies for months after the fresh fruit had disappeared from the markets.

THE INFLUENCE OF THE TYPE OF PACKAGE ON THE KEEPING QUALITY OF SMALL FRUITS.

In these experiments, the Hallock crate commonly used in the berry districts of Michigan and other Central Western States was tested in comparison with the open slat crate, with flaring baskets, used throughout the berry sections of the Middle and Southern States. Baskets used in the open-slat crates are shown in Plate III, figures 1 and 3. The Hallock crate holds 16 square quart boxes, made of veneer with raised bottoms, and is a somewhat tighter package than the slat crate. A Hallock crate is shown in Plate II, figure 3. The Hallock box, shown in Plate II, figure 2, is also much tighter than the berry

basket used in the eastern crate. These two crates are the standard berry packages for the eastern United States. A series of tests developed the fact that not enough difference in the tightness of the two packages exists to materially affect the keeping of the fruit in cold storage. Practically the same amount of mold developed in the fruit in one package as in the other, and neither seemed superior to the other in affecting the length of time the fruit kept.

With a view to testing the effect of a close package upon the keeping of berries in cold storage, a considerable quantity of fruit was stored in the cartons before mentioned. The carton used holds a little less than a quart, and is manufactured and used by a confectionery firm for the purpose of preserving pop corn and other confections in a dry, crisp condition. The package is a very close one, well designed for protecting the contents from contact with the air. Fruit packed in these boxes in a dry, firm condition kept well, being much less affected by mold and less tainted by storage-house odors than the fruit stored in open packages. Fruit that was damp with rain or dew when packed, however, fermented and turned brown in three or four days. A still tighter package, made by wrapping and sealing the paraffined cardboard carton in a heavy paraffined paper wrap before inclosing it in the outside paper jacket, was tested during the season of 1905. This package proved too tight; the fruit softened and had the characteristic bad flavor of fruit confined and smothered in an atmosphere of carbon dioxide.

COMPOSITION OF THE AIR IN DIFFERENT TYPES OF PACKAGES.

In order to test the comparative tightness of the several packages and to determine the effect of a close package on the air surrounding the fruit, a series of chemical tests of the air in the packages was made in cooperation with Mr. H. C. Gore, assistant chemist, in the Bureau of Chemistry. Packages of fruit were prepared in the berry field and were placed in cold storage at 36° F. two to four hours later. The packages used were the double-wrapped and the triple-wrapped cartons previously described and glass bottles with rubber stoppers. Within four to ten days after the fruit was stored Mr. Gore analyzed samples of the gases taken from the several styles of packages.

The method of taking the samples of gas was as follows: A round hole was punched in one end of the box and a glass tube was immediately inserted nearly the whole length of the box. This glass tube was connected with a rubber tube attached to a 6-ounce bottle. The bottle, rubber tube, and glass tube had been previously filled with water. By gentle suction a sample of air 60 to 80 cubic centimeters in volume was drawn from the package and was immediately analyzed. In taking samples from the bottles the glass tube of water was inserted through

an opening made by removing a glass plug from the stopper of the bottle. By these methods of taking the gas samples some admixture with the outside air is possible, but it was evidently not sufficient to vitiate the results in a comparative study of this kind. Table I shows the result of these analyses.

TABLE I.—*Analyses of gas in strawberry packages.*

Variety.	Date of picking.	Date of analysis.	Volume of sample analyzed.	Character of wrapper.	Carbon dioxide found.	Oxygen found.
	1905.	1905.	<i>Cubic centimeters.</i>		<i>Per cent by volume.</i>	<i>Per cent by volume.</i>
Gandy.....	June 5	June 15	62.2	Double wrapper	2.09	17.5
Do.....	do	do	86.0	do.....	1.86	18.6
Do.....	June 9	do	73.7	do.....	1.49	20.0
Do.....	do	do	100.0	do.....	1.40	18.8
Do.....	do	do	78.2	Triple wrapper	9.8	12.8
Do.....	do	do	100.0	do.....	7.16	13.6
Do.....	June 16	June 19	100.0	Tightly closed bottles.....	37.2	0
Do.....	do	do	86.4	do.....	36.3	0.2
Do.....	do	do	100.0	do.....	37.6	0
Do.....	do	do	63.4	do.....	34.3	0
Average for tightly closed bottles					36.4	

It will be seen from the above table that the samples taken from the ordinary double-wrapped cartons show a low percentage of carbon dioxide and a high percentage of oxygen. This indicates that the double-wrapped package is not very tight, comparatively speaking, as the amount of carbon dioxide retained increases with the tightness of the package. The samples taken from the triple-wrapped carton show much more carbon dioxide and much less oxygen, indicating that the triple-wrapped package is much tighter than the double-wrapped package. The samples taken from the tightly stoppered glass bottles show a still larger percentage of carbon dioxide and an almost entire lack of oxygen, indicating a high degree of tightness. In these receptacles practically all of the oxygen in the confined air was replaced by carbon dioxide, and about 15 per cent in addition was produced by the fruit.

The flavor of the fruit in the double-wrapped boxes was very good at the time the gas samples were taken, and the berries were still firm and sound. In the triple-wrapped box the fruit had softened considerably and had a bad flavor. The fruit in the glass bottles was softer than that in the triple-wrapped boxes and the flavor was very bad. The poor flavor, together with the softening of the texture, was undoubtedly due to the smothering of the fruit by the large amount of carbon-dioxide gas.

A fruit as taken from the tree or plant is a living, breathing organism. It takes in oxygen and gives off carbon dioxide. It can not be held in a tight package in an atmosphere of carbon dioxide exhaled by the fruit itself without killing it or injuring it severely. This is appar-

ently what occurred in the triple-wrapped cartons and in the glass bottles. However, in the practical application of a close package to fruit storage, smothering would not be likely to occur, as a package tighter than the double-wrapped box would rarely, if ever, be used. Fruit appears to be damaged little, if any, in keeping quality or in flavor by the presence of a small amount of carbon dioxide in the air of the storage room, and only in the presence of a large amount of this gas does real injury occur. Commercial packages which are generally used in storing fruit are not sufficiently tight to retain a considerable amount of carbon dioxide. There might be some injury in a moderately close package if the fruit was not stored quickly after it was picked and packed. The life processes of the fruit are much accelerated at this time, particularly in warm weather, and under these conditions enough carbon dioxide might be given off and retained by the package to injure the quality of the fruit before it was stored. In cold storage, however, the life processes are retarded quickly by the low temperature, respiration progresses much more slowly, less carbon dioxide is given off, and therefore there is less danger of injury from this source.

THE INFLUENCE OF THE WRAPPER ON THE KEEPING QUALITY OF SMALL FRUITS.

At the present time no tight berry package is manufactured. A few northern growers are using paper wrappers on berry boxes, which is a step in the direction of a close package. In the tests of the Bureau of Plant Industry impervious japanin paper was used upon a considerable quantity of fruit stored, each box being wrapped separately. Berry boxes wrapped in japanin paper are shown in Plate II, figures 2 and 3. The wrapper aided materially in retaining the bright color and attractive appearance of the fruit and prevented the absorption of storage-house odors to a marked degree. It also retarded to some extent the appearance of mold. In preventing the tainting from storage-house odors alone, the moderately tight package or the use of the wrapper has proved of great value.

During the season of 1905 a test of wrapping crates of strawberries of the Gandy and Tennessee varieties in heavy manila paper was made, the entire crate being covered with paper instead of wrapping the individual baskets. While this treatment did not result in materially diminishing the amount of mold which developed on the fruit, it did prove efficient in preventing the tainting of the fruit from storage-house odors. Berries in adjoining unwrapped packages became so contaminated with odors from other products in the storage room that the fruit was quite unpalatable in a few days, while the berries in the wrapped crates remained entirely free from such contamination.

Aside from the protection afforded berries by its use, the wrapper also adds to the attractiveness of a berry box. The idea of rendering the package more attractive has probably been the dominating one with the berry growers who have made use of the wrapper, but, as previously shown, its usefulness does not end with its esthetic value.

In commercial cold storage, single rooms in storage houses are frequently used for a wide range of commodities during the summer months. It is not uncommon to find vegetables of various kinds and even citrus fruits stored in the same room with berries. In a poorly ventilated room, the odors arising from these products are quickly absorbed by the berries, rendering the flavor of the fruit objectionable. The fruit lacks wholesomeness, and is therefore objectionable to the consumer, though it may be bright in color and of sound physiological condition.^a

THE INFLUENCE OF OXYGEN GAS ON THE KEEPING QUALITY OF SMALL FRUITS.

As the keeping quality of the small fruits was injured when they were stored in an atmosphere containing an excess of carbon dioxide, some tests were made by Mr. Gore to determine the influence of storing strawberries and raspberries in an atmosphere containing an excess of oxygen.

The strawberries used for the test were of the Gandy variety. A few berries were soft when stored, but most of the fruit was firm and dry. Several boxes were exposed to the usual conditions of the open package, and several were kept in a large glass bell jar, which closely fitted a ground glass plate. The air in this jar was then displaced with oxygen of 90 to 95 per cent purity, and was renewed at intervals

^a The factors that influence the wholesomeness of a fruit in cold storage are complex in nature. It is generally supposed that good quality is determined principally by the length of time the fruit has been stored. The question, however, is more complicated than this. The physical condition and flavor of the fruit at any period in its storage life may be influenced by the weather conditions surrounding it before it is stored or by a delay in storing the fruit, both of which may cause it to expend a large part of its life before it is stored; they may be modified by the relation the package or wrapper bears to the proper ventilation of the fruit or to the exclusion of the impure air of the storage house; they may be modified by the rapidity of cooling the produce after it is placed in the warehouse, by the relation of the storage-house temperature to the life processes of the fruit, by the ventilation of the warehouse, and finally by the effect of the length of time the fruit is in storage on all of these factors. Until recently little attention has been paid to the factors that affect the wholesomeness of cold-storage fruits, except the length of time a product is stored and the temperature in which it is stored in the warehouse. The work of the Bureau of Plant Industry along fruit-storage lines has emphasized the fact that the question is much broader than is generally believed and that it needs careful experimental consideration from several standpoints.—G. H. P.

of two to four days throughout the experiment. After an interval of sixteen days the jars were opened and the fruit compared with that stored in the exposed boxes.

The fruit held in oxygen had a good color and flavor, but had softened so as to be entirely unmarketable. It was free from black mold. The fruit held in open boxes had a good color, but a bad flavor, and it was badly molded. It was unmarketable. The difference between the two lots was about that which occurs when the fruit is stored for the same length of time in open and closed packages. No effect due primarily to the oxygen gas was apparent.

For the raspberry test, Kansas blackcaps were used. The fruit was in first-class condition, dry and firm, when stored. Several boxes were left under the usual storage conditions, several were kept in a bell jar in confined air, and several were kept in a bell jar in oxygen, the gas being frequently renewed. After an interval of thirty-nine days the fruit was examined. The berries in the open boxes had sunk down so that they filled the boxes not more than half full. They had molded badly. The fruit confined in air in the bell jar was in good physical condition. The berries were dry and free from mold. The flavor, however, was insipid. The fruit kept in oxygen was also in good physical condition. The berries were dry and free from mold, but the flavor was quite insipid. No effect attributable to the presence of oxygen was brought out. As in the case of the strawberries, the better condition of the inclosed fruit over that of the exposed fruit was due apparently to the influence of the close receptacle.

THE INFLUENCE ON THE KEEPING QUALITY OF CAREFUL HANDLING AND OF STORING SMALL FRUITS SOON AFTER PICKING.

The most serious troubles with small fruits in cold storage are the quick loss in flavor when they are stored in impure air, the softening of the fruit from overripeness, and the molding or decay, especially of raspberries, strawberries, blackberries, dewberries, and currants. The mold usually appears a few days after the fruit is stored. It is a fungus called *Botrytis vulgaris*, commonly known as black mold. Molded berries are shown in Plate I, *D*, and in Plate III. It is especially serious in small fruits that have been handled roughly and that are not stored soon after picking. A berry picked in a dry, sound, firm condition is not often attacked by the black mold. Overripe berries and berries with the surface bruised nearly always mold. The mold gains entrance through the bruised or weakened parts of the fruit, creeping over the berries in the form of a cotton-like covering or mycelium. It grows luxuriantly in warm temperatures and slowly in the coldest temperatures in which the fruit can be stored safely without freezing. It is most troublesome on raspberries.

The most successful method of preventing this trouble is to store only sound, firm berries. To prevent the trouble is primarily a problem of picking and handling. It is necessary that the pickers do not injure the berries, and that they be handled through every operation from the crating to the market with enough care to prevent the bruising of the delicate fruit. A large proportion of the commercial losses in the shipping and handling of small fruits is the direct result of the rough handling which makes them susceptible to mold or decay.

In addition to the loss from mold, the bruised portions of small fruits quickly discolor in the storage house, as shown in the frontispiece, Plate I, *C* and *D*.

Quick storage or cooling after picking is an equally important requirement in small-fruit storage. The life processes need to be checked at the earliest possible moment to prevent overripeness and to conserve the flavor of the fruit by preventing the giving off and accumulation of carbon dioxide and the absorption of odors from the surrounding air. The fruit needs to be cooled quickly, also, to retard the growth of the molds already mentioned. If the fruit stands in the field or in a packing house or at a railroad station for some time before loading, if it is hot when loaded and is shipped by express or by freight without ice, if it is not cooled down quickly in the car when shipped in refrigeration, or if the fruit is held in the market for some time after arrival it is impossible to place it in cold storage without the subsequent development of bad flavor, overripeness, and moldy or decayed fruit.

THE LENGTH OF TIME SMALL FRUITS KEEP IN COLD STORAGE.

The length of time small fruits keep in cold storage depends upon the variety, the conditions under which the fruits are grown, and the methods of handling them in picking, packing, shipping, etc. In the Department tests, with fruit handled under good commercial conditions, strawberries kept from one to two weeks in good condition so far as appearances were concerned, but the flavor usually began to deteriorate after three or four days. Some of the firm-fleshed varieties, like Gandy, kept even longer than two weeks when picked dry and carefully handled, while tender varieties, like Tennessee, went down much more quickly. Red raspberries usually began to mold after two or three days in storage. Black raspberries kept in sound condition for a somewhat longer period. Most varieties of blackberries kept a week, while some of the firmer fleshed sorts kept several days longer. Dewberries behaved similar to blackberries. Currants kept well for two weeks with slight loss of flavor. Gooseberries retained their normal appearance and flavor for two to three weeks, after which the fruit

turned red and became unsalable. Cranberries kept throughout the winter and were withdrawn the last of April in good commercial condition.

These statements are based upon tests with small fruits packed in the customary way as for market and stored in a temperature of 32° F. Wrapped fruit and fruit stored in moderately tight packages kept for somewhat longer periods.

THE BEHAVIOR OF SMALL FRUITS WHEN WITHDRAWN FROM COLD STORAGE.

Small fruits do not hold up long after withdrawal from cold storage on account of their highly perishable nature. In the tests of the Bureau of Plant Industry strawberries, raspberries, and blackberries which had been stored for several days usually began to break down within six to sixteen hours after removal from storage, while currants and gooseberries held up from twelve to twenty-four hours, or even longer.

Small fruits need to be placed in the hands of the consumer as quickly as possible after removal from cold storage. If disposed of quickly after withdrawal, small fruits which have not been stored too long or subjected to unfavorable conditions in handling or storing will be in wholesome condition about as long as fruit in similar condition of ripeness and soundness that has not been in cold storage.

SUMMARY.

Cold storage has not exerted so important an influence upon the development of the small-fruit business as upon the growing of apples, pears, and other tree fruits. Small fruits are not adapted to keeping for any length of time in cold storage.

Most of the small fruits are held in cold storage to protect them from decay, usually not more than two or three days, until they can be placed in the hands of the consumer.

Nevertheless cold storage is a factor of no small importance in the handling of the small-fruit crop. Shipments of small fruits reaching destination too late for the early morning market are usually placed in cold storage until the following morning. Large quantities of small fruits are stored for two or three days when the markets are glutted and when prospects are good for an advance in prices. Many canneries are equipped with cold storage plants for use in preserving berries and other fruits until they can be utilized. In some sections small farm storage houses are used in connection with the handling of small fruits. Small fruits are sometimes stored in a frozen condition

for weeks and even months for use by confectioners, bakers, and restaurateurs.

Berries grown to a large size upon low, moist soil usually begin to break down more quickly in cold storage than the same varieties grown to a somewhat smaller size upon light, dry soil.

Berries ripening during a period when the supply of moisture is favorable for a sound, healthy development of fruit keep better than the same varieties stunted by drought or overgrown on account of excessive rainfall.

Small fruits designed for cold storage should be picked when well matured and fully colored but while still firm.

There is no apparent difference in the keeping of small fruits from early, medium, and late pickings.

Small fruits must be handled quickly and with great care in the field and on the way to the storage house to prevent ripening, the bruising of the fruit, and the development of mold.

If the fruit is to be stored for two or three days, a temperature of 36° to 40° F. will ordinarily give satisfactory results, though a temperature of 32° F. is to be preferred. If the storage period extends over a week or more, a temperature of 30° to 32° F. will be found more effective.

When frozen for long keeping, small fruits are usually subjected to a temperature of 5° to 12° F.

Frozen strawberries to be used in ice cream have been in use in a limited way by confectioners for some time, while frozen raspberries, currants, blackberries, huckleberries, and other small fruits are now used successfully for pies and other pastries by a few restaurateurs and bakers.

Strawberries and raspberries were stored in close paper cartons lined with paraffined cardboard. Some of these cartons were made extra tight by the use of a paraffined paper wrap placed over the cardboard liner of the carton. The cartons without the extra wrap preserved the fruit in good, sound condition, freer from mold and tainted less by storage-house odors than fruit stored in open packages. With the extra wrap the cartons proved too tight; the fruit softened and had the characteristic bad flavor of fruit confined in an atmosphere of carbon dioxide.

Wrapping baskets of berries in thin impervious paper aids materially in retaining the bright color and attractive appearance of the fruit, prevents the absorption of storage-house odors to a marked degree, and retards to some extent the appearance of mold.

Strawberries were kept in good condition in cold storage from one to two weeks; red raspberries, two to three days; black raspberries,

three to five days; blackberries and dewberries, from a week to ten days, and currants, two to three weeks. Cranberries kept all winter.

Strawberries, raspberries, and blackberries which have been stored for several days usually begin to break down within ten to twelve hours after removal from storage, while currants and gooseberries hold up from twelve to twenty-four hours longer.

Upon removal from cold storage small fruits should be placed in the hands of the consumers as soon as possible.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. *Frontispiece*. Gandy strawberries. A shows the condition of the fruit after twenty-one days in cold storage at a temperature of 32° F. The fruit was firm, bright, and normal in appearance on withdrawal from the storage house, but the flavor was gone. B shows the condition of the fruit after more than seven months in cold storage in a frozen condition at a temperature of 12° F. C shows the discoloration of the fruit from bruising. D shows mold growing over a bruised spot.

PLATE II. Packages and wrappers used on berries in cold storage. Fig. 1.—Cartons in which berries were frozen. Fig. 2.—Strawberries wrapped with japanin paper and a box of unwrapped fruit. Fig. 3.—Black raspberries in a Hallock crate, unwrapped and wrapped with japanin paper.

PLATE III. Black mold on strawberries and black raspberries in cold storage. Figs. 1 and 2.—Black raspberries showing mold in cold storage. Figs. 3 and 4.—Black mold on strawberries in cold storage. The white mycelial threads holding the berries together and spreading over them are shown.

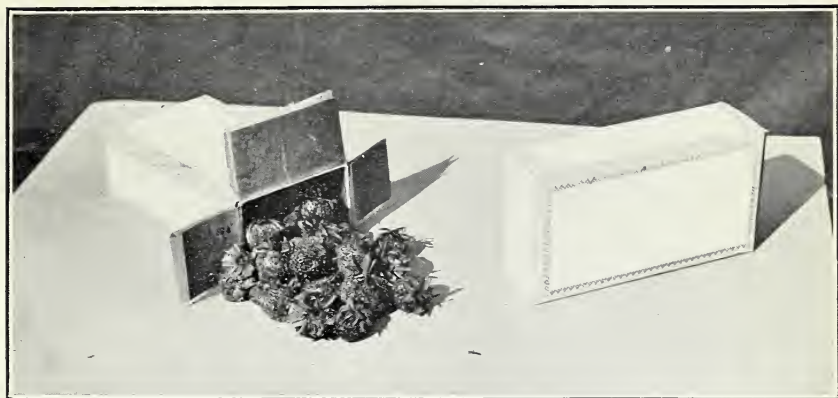


FIG. 1.—CARTONS IN WHICH FRUIT WAS FROZEN.



FIG. 2.—A BOX OF STRAWBERRIES WRAPPED WITH JAPANIN PAPER AND ONE UNWRAPPED.

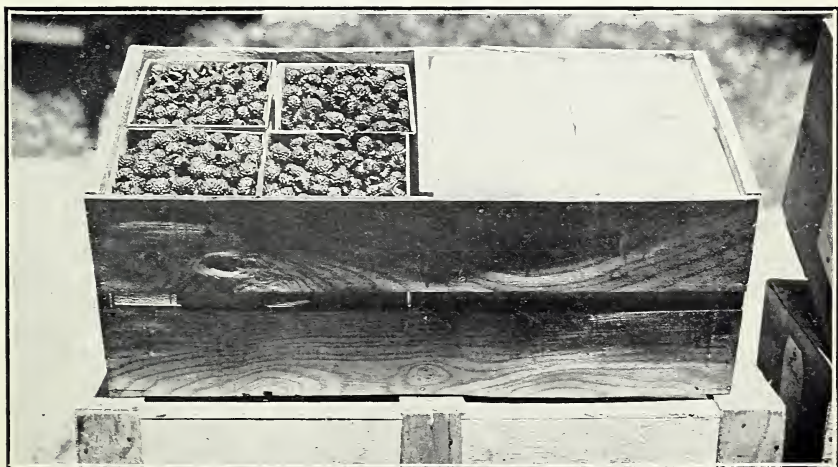
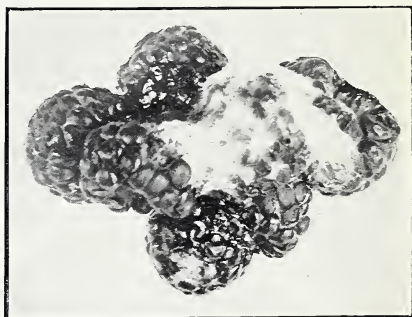
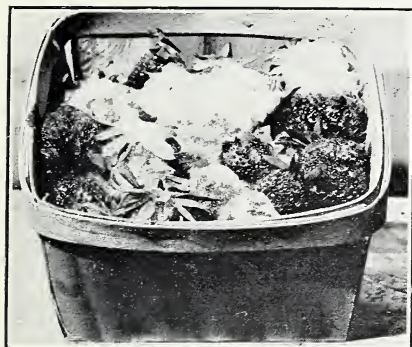


FIG. 3.—BLACK RASPBERRIES WRAPPED IN JAPANIN PAPER AND UNWRAPPED, PACKED IN A HALLOCK CRATE.

PACKAGES AND WRAPPERS USED ON BERRIES IN COLD STORAGE.



FIGS. 1 AND 2.—BLACK MOLD ON BLACK RASPBERRIES.



FIGS. 3 AND 4.—BLACK MOLD ON STRAWBERRIES.

BLACK MOLD ON STRAWBERRIES AND BLACK RASPBERRIES IN COLD STORAGE.

Al
Be
Bl
Bl
Bo
Ca
Ca
Ca
Cl
Co
Co
Cr
Cr
De
Ev
Ex
Fa
Fl
Fr
Fr

Gas
Go
Gre
Ha
Ke

INDEX.

	Page.
Air in different types of packages, composition.....	15-17
Behavior of small fruits when withdrawn from cold storage.....	21
Blackberries, varieties tested in storage.....	10
Black mold, cause.....	19
<i>Botrytis vulgaris</i> , cause of black mold.....	19
Canneries equipped with storage houses.....	8, 21
Carbon dioxid, injurious effects in sealed packages.....	15
Cartons used for berries in storage tests.....	11, 15
Climatic conditions, influence on keeping quality of fruits.....	11
Cold storage of different fruits, purposes.....	7
Cranberries, varieties tested in storage.....	10
Crates, kinds used in storage tests.....	11, 14-15
Dewberries, varieties tested in storage.....	10
Evaporation, methods of overcoming, in freezing fruits.....	13
Experiments outlined.....	10-11
Farm storage houses used for small fruits.....	8
Flavor, absorption of storage-house odors, methods of control.....	17
frozen fruits, influence of package.....	13-14
stored fruits, influence of tight package.....	16
Freezing fruits for use by confectioners and bakers.....	8, 13-14
methods of overcoming evaporation.....	13
Fruits, frozen, flavor, methods of control.....	17
influence of package on quality.....	13-14
length of storage.....	14, 20
purposes.....	7
temperature during storage.....	12-14
used by confectioners and bakers.....	13-14
in farm storage houses.....	8
keeping quality, influence of careful handling.....	19-20
climatic conditions.....	11
oxygen.....	18-19
size of berry.....	11
kinds tested in storage.....	10
Gases in sealed packages of berries, composition.....	15-17
Gooseberries, varieties tested in storage.....	10
Great Britain, report of fruit storage test in 1898.....	9
Handling, careful, influence on keeping quality.....	19-20
Keeping quality, behavior after storage.....	21
controlling factors.....	10
influence of careful handling.....	19-20
oxygen gas.....	18-19
storing soon after picking.....	19-20
type of package.....	14-15
wrapper.....	17-18

	Page.
Maturity, degree best for storage	12
New York, extent of small fruits stored	8
Oxygen, influence on keeping quality of small fruits	18-19
Package best suited for freezing fruit	13
gas surrounding fruit	15-17
kinds used in storing small fruits	11, 14-15
sealed, for freezing berries, effect	15
Paper, japanin, for wrapping fruit	11
paraffin, for wrapping fruit	11
Plates, description	26
Quality, behavior after storage	21
keeping, controlling factors	10
influence of careful handling	19-20
climatic conditions	11
oxygen	18-19
size of berry	11
methods of preserving, in storage	17
retention in storage	20
storage-house odors, influence	17
Raspberries, varieties tested in storage	10
Size of berry, influence on keeping quality	11
Soils, influence on keeping quality of small fruits	11
kinds on which fruit tested was grown	11
Storage, cartons used for berries in tests	11, 15
crates used in tests	11, 14-15
duration for different small fruits	14, 20
prompt, importance for best results	19-20
temperatures	12-14
varieties of small fruits tested	10
Strawberries, varieties tested in storage	10
Summary	21-23
Temperature best for ordinary storage	12
freezing storage	13
Time small fruits keep in cold storage	20-21
Varieties of small fruits tested in storage	10
Wholesomeness of stored fruits, factors influencing	18
Wrappers for small fruits, kinds tested	11



